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PUBLICATIONS OF THE
BIOLOGICAL BOARD OF CANADA

ON *CLUPEA PALLASII* CUVIER AND VALENCIENNES

ICHTHYOLOGICAL NOTES ON:

I. *OPHIODON ELONGATUS* GIRARD;
II. *ONCORHYNCHUS KETA* WALBAUM;
III. THE DIAGNOSIS OF FISH BY MEANS OF THE SCALES;
IV. *MALLOTUS VILLOSUS* MÜLLER.

BY
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ON *CLUPEA PALLASII* CUVIER AND VALENCIENNES

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Plates VIII and IX

Spawning Habits

The points of resemblance in the Pacific herring (*Clupea pallasii*) and the Atlantic herring (*C. harengus*) are more noticeable than the points of difference, but although this is so, the points of difference are [illegible] importance to make interesting a special study of the life-history of the Pacific species. Even if there were not such differences, it would be worth while, as there is so much unknown or in dispute in reference to the Atlantic species.

Judging from the description given in Jordan and Evermann,[1] one should expect to find the Pacific herring larger than the Altantic, but that does not seem to be the case in any herring of the Pacific Coast, with the possible exception of those around the shores of Northwestern Alaska. The Atlantic herring is said to be 16 inches in length, while the length of the Pacific herring is given as 18 inches. 16 inches may be a good length for an Atlantic herring, but certainly 18 inches is decidedly wide of the mark as a measurement of the herring that are fished now-a-days in the Strait of Georgia. Measurements of several hundreds of fish have been taken, and these have been collected from thousands of tons of fish, but no fish was obtained with a greater length than 10 inches, measured from the tip of the nose, or rather the lower jaw, to the beginning of the rays in the caudal fin. To be exact, the greatest length was 24.6 cm. or 9.8 inches. The average length was about 20 cm. or 8 in. The average of 80 females taken at various times throughout the year was 20.3 cm. while the average of the same number of males under similar conditions was 19.7 cm. The females averaged 106.2 grams (3.8 oz.) and the males 94.4 grams (3.4 oz.). These were caught with the seine and consequently included some that were quite small (as short as 15 cm.), but they would come very nearly being the average of the total catch of the season from this district.

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[1] "Fishes of North and Middle America." Bulletin 47, U.S. National Museum, 1896, pp. 421-2.

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The spawning habits of the Atlantic herring have been the cause of differences of opinion since the first investigation was made on this species, and even yet there is much lack of agreement concerning them. Are the winter herring and the summer herring the same, the individual spawning twice in the year or are they entirely different races, the individual spawning but once in the year but those of different races spawning at different seasons?

From all the evidence so far deduced there is not much room for such difference of opinion in the case of the Pacific herring. Apparently in no case has spawning been observed twice in the same year in any one district. The spawning time varies somewhat with the locality, as it does with either the winter herring or the summer herring in the North Sea, but in any one locality the spawning all takes place within a few days and there is no further indication of it until approximately the same time the next year. If a more extended series of observations corroborates what thus far seems quite certain, circumstantial evidence would indicate that the Atlantic herring spawn but once in the year, since the two species, in their general structure as well as in their habits, are so closely related. Direct investigation has been restricted almost entirely to the area within a radius of 20 or 25 miles from the Biological Station, Departure Bay, but as this area includes the most important herring district in British Columbia waters, it is large enough to provide material for a great amount of work, so much so, that what is already done can only be considered as a preliminary to a prolonged attack on the herring problem. The investigation is made all the more agreeable on account of the courtesy the local representatives of the Fisheries Department as well as all others from whom it has been necessary to obtain information or assistance.

Within this area, during the seasons 1912-3 and 1913-4, the herring made their first appearance for the season at the entrance to Nanoose Bay, in 10-20 fathoms, about the first of October. At this time the gonads are partially developed, the eggs being from one-fourth to one-half the diameter of the full grown eggs. They remained in this vicinity in sufficient numbers for four or five weeks to make it profitable to fish for them and then they disappeared. About the same time a sufficient number appeared to the southward of Yellow Point to attract the fishermen in that direction. These localities are 30 miles or more apart, and it is scarcely probable that the same race of fish are found in the two places. If the one school travelled from one place to the other along the shore or even a short distance out, some of the fishermen, who at this time are continually on the lookout for them, would be sure to see some trace of them on the way. Furthermore, coho salmon caught in

October and November and spring salmon later off West Rocks and Five Finger Islands commonly contain mature herring. Seals killed in the vicinity of Nanoose Bay contained many of them, but as the seal is a strong swimmer it might go out some distance to sea when necessary to secure a sufficient supply of food. It is generally credited with a fondness for salmon, but there is plenty of evidence to show that the herring are not rejected, although they may be taken only when more tasty food is scarce. Such indications of the occurrence of herring in the neighbourhood is too common to make it possible to believe that even the larger body of those making their appearance early migrate southward soon afterward.

After fishing for a short time near Yellow Point the fishermen moved to Cowichan Gap (Porlier Pass), in the neighborhood of which they remained for several weeks, working gradually northwest from this again by way of Gabriola Pass and Northumberland Channel to points near Nanaimo, where the last fishing of the season (Feb. 28) was done. (Gill netting and line fishing is carried on more or less throughout the whole year). Practically all of the fishing until within a short time of the spawning season is done in much the same depth of water (15-25 fathoms).

For a week or two before spawning the Pacific herring are so devoid of fat that they are not very palatable and after they are spent they are no better for some time. For that reason as well as to protect them during spawning, restrictive regulations have been framed to prevent as much as possible the catching of them after they show signs of spawning.

In fish caught soon after spawning the gonads are so shrunken as to be scarcely noticeable, and they show but little change for two months or more. Then enlargement begins, but very slowly at first, so that even at the end of June, four months after spawning, each gonad usually weighs less than a gram. After this there are greater differences in development in different fish, probably depending somewhat on the age of the fish. At the end of six months they vary in weight from 2 to 4 or even 5 grams and are from one-quarter to one-half the size of the full grown gonad. The development during the last six months is as gradual as during the first six. At any one time the weight of the gonad bears a fairly definite ratio to the weight of the entire fish. The increase in the size of the egg will indicate the rate of enlargement of the gonad. Average eggs from fish obtained Oct. 10 were 0.7 mm. in diameter, Nov. 9, .85 to 0.9 mm., Dec. 12, 1.0 to 1.05, Jan. 28, 1.1 to 1.2; Feb. 8, 1.25 to 1.30; Feb. 22, 1.35 to 1.40; Feb. 28, 1.4 to 1.6 (spawned). This offers rather conclusive evidence that the Pacific herring at least spawns but once in the year.

It has been stated repeatedly by investigators who have worked on the North Sea herring that these come back to the identical place to spawn year after year. If one is to judge from the distribution of spawning areas in the spring of 1913 and 1914 that cannot be said of the Pacific species, as the distribution was quite different in the two years. In 1913 spawn was deposited thickly in Nanoose Bay well up at the head of the Bay and from there along the shore east all the way to Horswell Rock as well as everywhere in Departure Bay, while in 1914, there was none deposited at the head of Nanoose Bay, but there was some at the entrance to the Bay and for three or four miles to the eastward, but none the remainder of the way to Horswell Rock and none in Departure Bay.

Apparently there is not the same trouble here in locating herring spawn as there is in the North Sea. In fact there is no trouble at all. The spring tide rise is up to 16 feet or more. At or near high tide a school of herring passes into a Bay or into shallow water along the shore and there the females move in and out among the seaweed or eel grass, depositing the eggs as they rub against these solid objects. There the eggs adhere not only to the seaweed but to some extent to one another. In the meantime the males extrude the milt in such abundance that when it mixes with the water, the water becomes almost perfectly opaque, of a light greenish-white color. Before the tide goes down the eggs are practically all fertilised and at low tide—sometimes even at half-tide—are exposed in such large quantities that no one going near could fail to see them. The ripple caused by the fish in the water,—although this may be seen at any time when a school of herring is passing—the peculiar opacity of the water, the flocks of gulls that follow the progress of the school, the masses of eggs exposed later, inconceivably numerous, with hordes of ducks doing their best to reduce the number, each and all give unmistakeable evidence as to the locality where spawning takes place.

Although the eggs are out of the water for four or five hours at a stretch they do not seem to suffer. The bladder wrack or eel grass might retain a certain amount of moisture, but the eggs are often found attached to the bare rock, and here the moisture cannot be retained.

To see the thoroughness with which the milt is mixed with the water one wonders if it could be possible if any eggs could escape contact with some of it, but later, when one sees the spawn exposed, so many eggs in so small a space and so much space occupied, one can scarcely realise, even after seeing the method of distributing the milt, that provision could be sufficiently thorough to ensure the fertilization of every egg. The egg is so transparent that the dark eyes of the embryo, shortly before hatching, are very conspicuous, hence a glance is all that is necessary to see if the egg is fertile. In mass the bad eggs are much lighter in color than are the fertile eggs. The eggs are deposited in a strip averaging from two to four rods wide near low tide, but above it at spring tide. It can be stated from personal observation that it is possible to walk for a quarter of a mile or more along such a strip without finding a single mass of bad eggs, although a mass covering a few square inches might be found occasionally. Taking into consideration that in many instances ten million eggs to the square foot would be a low estimate, the thoroughness of the fertilisation process may receive its proper appreciation. It is quite possible that the number of individual bad eggs in the smaller masses may bear a smaller ratio to the total number in the mass than the small masses of bad eggs bear to the number of such small masses in a large area. The evidence points that way. On a piece of eel grass 6 inches long there may be 300,000 eggs. The closest scrutiny will fail to reveal a single bad egg in the whole mass. Out of every egg in the mass, two bright, dark eyes shine forth, and as one looks at them with a lens every little herring will roll over in his shell to show that there is activity behind the dark eyes. Such an observation has been repeated over and over again with the same result almost invariably. Unless the eggs are laid too close to the surface so that the water subsides before they are fertilised or unless they are covered up in some quiet spot immediately after deposition, their fertilisation is practically a certainty.

Spawn may be deposited in an area of this nature practically uninterrupted for 15 miles or more within a period of three or four days, which would indicate that it all comes from the same local race of herring. After the ducks have had their share and the various shore and shallow water fish have had their quota and other enemies have helped themselves, it is quite probable that there would still be left on an average as many as a million to the square foot to hatch out. At such a rate the whole of such an area as that above mentioned would liberate about 4,000,000,000,000 young herring in one season. Such an area would be repeated several times along the coast of Vancouver Island, but to keep the figures conservative let us suppose that the fish caught by the Nanaimo fishermen came from this same race of fish. The catch for 1912-3 was approximately 25,000 tons. Taking 3.6 ounces as the average weight of a herring, there would be about 9,000 fish to the ton and in 25,000 tons there would be 225,000,000 fish. That number would be $\frac{1}{200}$ of one per cent. of the number given in the above estimate, or 1 in 20,000. It is quite evident that man's endeavor to thin out the species is thus far of little significance. When the herring come into the shallow water to spawn they can be caught with the greatest ease and in the greatest numbers, but, as before stated, at this time they are not suitable for eating fresh, for dry salting, pickling or smoking. So unsuitable are they that any caught at this time and put on the market are apt to ruin the market for good fish. If, then, the fish are carefully protected during the spawning period, there seems to be no reason to believe that there would be danger of over fishing even if the amount caught was increased to many times the present amount. Furthermore, if all the fish shipped were in good condition, there would be little likelihood of a glutted market, even if the supply were greatly increased.

With the assistance of Mr. H. McIndoo, Fisheries Overseer, we were able to get a good idea of the times and places where spawning took place during the spring of this year (1914). The information thus obtained tends to confirm the opinion that there are different schools or races corresponding to the different localities where fish are caught in quantity during the season. Indians reported the first spawn of the season from Yellow Point on Feb. 20. No spawn was received from that locality, but doubtless the report was correct. On Feb. 26 and 27 there was an abundance of spawn deposited around Breakwater Island, through Gabriola Pass and the north shore of Pylades Channel between Gabriola Pass and False Narrows. On March 2 there was strong evidence of milt at the southeast end of Northumberland Channel in the neighborhood of Percy Anchorage, but this must have been due either to the presence of some coming through False Narrows with the current or to the fact that large hauls of fish were being made near by in the Channel and the rough handling caused a certain amount to be dehisced. This is often noticeable near where fish are being taken out of a seine. At any rate careful examination later failed to reveal any spawn in the channel. On March 9, Pilot Bay at the north end of Gabriola Island was filled with milt, and spawn was deposited in large quantities. From Pilot Bay eastward to Berry Point—the northeastern point of the island—spawning took place during the two following days. The northeast coast of Gabriola Island from Berry Point to the Flat Top Islands was visited March 12 and 13, continuing on the east side of the Island until March 17. In the meantime spawning was reported from Big Qualicum on March 8 and from the entrance of Nanoose Bay for three or four miles eastward on March 10. Mr. McIndoo found herring spawning at Ganges Harbor, Saltspring Island, on March 20, but this locality is so far away from this district where close observations were made that it can scarcely be included in any generalisation. Within the district we have quite complete data except for Cowichan Gap and the neighboring portion of Valdez Island, from which we have no records.

The spawning areas agree very well with the areas in which the herring appear in numbers earlier in the season. It would seem that one race spawned in Kulleet Bay (Chemainus Bay) from Yellow Point South. One should infer that another race spawned at Cowichan Gap, but we have no record of this. Another race spawned from Breakwater Island, through Gabriola Pass to Pylades Channel, one to the north and east of Gabriola Island and one from Qualicum to Nanoose Bay and a little farther eastward. All of these places were fished extensively with the exception of the north and east of Gabriola Island, where the eastern and southeastern storms of the winter season make fishing a troublesome occupation. Apart from these localities, extensive fishing was done in Northumberland Channel along the shore southeast from Jack Point. This race was fished until March 2, when large hauls were made in the channel just off the entrance to Dodds Narrows. These fish apparently passed through Dodds Narrows, as they appeared in large numbers on the Mudge Island shore and in the neighborhood of Round Island on March 5, but there was no sign of spawning here. They must have gone on the southward, but we have no record as to where they spawned, although spawning must have taken place soon afterwards, since, as has been previously noted, some of them were spawning in the seine on March 2.

After spawning the herring pass out into deeper water, probably not so very far away, as they make occasional visits into shallow water during the remainder of the year. How common these visits are it is impossible to say, as there has been little observation made in that regard. Evidently there are inducements for such migrations other than the necessity of finding suitable spawning grounds. It would be useless to present any conclusions concerning migration, however, until these conclusions are backed by a greater amount of evidence. It might be noted, though, that the herring have not the same trouble to get into deep water here as they have in the North Sea, since a depth of 150 fathoms or even 200 may be reached in the Strait without going far from the shore.

EMBRYOLOGY AND LARVAL DEVELOPMENT

In the mature herring just before spawning the milt and roe make up a very noticeable proportion of the whole weight. The largest male gonad examined weighed 22.7 grams, and as the fish weighed 158 grams, the two gonads made up over 28 per cent. of the weight; the largest female gonad weighed 18.6 grams, the fish 151.5 grams, 24 per cent. of the total weight. Although the younger and smaller fish do not have as large gonads as the older and larger, the proportion to the whole weight seems to vary within a comparatively narrow range.

The eggs when ripe are 1.4 to 1.6 mm. in diameter and in weight run from 900 to 1000 to the gram weight of the ovary. In the female in which the single ovary weighed 18.6 grams there were approximately 35,000 eggs, but this size is exceptional, and in all probability there are few cases in which there are more than 30,000 even in the older fish, while in the younger a very much smaller number is found. In a single ovary there were 14,165 eggs—making 28,330 to the fish—by actual count, while in a smaller fish there were 9,489 eggs in one ovary or 18,978 eggs to the fish. The yolk fills a large portion of the egg membrane, and there are no oil globules present.

The development of the embryo in the egg is easily studied, as, not only is the membrane transparent so that the embryo and the yolk may be seen without difficulty, but it is also very tough so that the eggs will stand handling without causing harm to the embryo. The spawn from a ripe female may be squeezed out into a dish containing fresh sea water into which sufficient milt is put at the same time. The eggs adhere to the bottom of the dish, hence the water can be changed on them readily—twice a day being sufficient—so that little care is required to get the development to take place as successfully as if it were in the sea itself and therefore as satisfactorily as could be desired. It is possible to get all but the earliest stages readily by getting the seaweed at the spawning ground from time to time and keeping it fresh until the next lot is obtained. Unless new material is obtained often, this does not prove so satisfactory as hatching the eggs out in a dish with no seaweed in it, as when the seaweed is torn from the rocks it decays quickly and apparently poisons the water as the embryos, particularly if they are nearly hatched out, die off rapidly. As the spawn in the natural condition is subject to a variety of temperatures on account of being exposed directly to the sun while the tide is out, a constant temperature is not necessary when hatching eggs under observation. If the temperature is kept high, development takes place more rapidly within comparatively narrow limits, but there is a higher mortality. The best results are obtained when the temperature is kept much the same as the temperature of the sea water, which at that time is between 45° and 50° F., at which temperature, with other conditions satisfactory, there should be almost no loss. The rate of development considered in the following account corresponds to that which takes place at such a temperature.

Very soon after the ovum is shed the spermatozoon enters and fertilisation takes place. In less than two hours the first furrow in the germinal disc is distinctly visible, and in less than half an hour more the first division is completely through the disc. In three hours division has again taken place, from which times it proceeds regularly until by the end of 8 hours the mass has arrived at approximately the 32-celled stage. From this on the number of cells increases rapidly, so much so that at the end of 12 hours almost one-fourth of the surface of the yolk is covered with the cellular disc, which is not very distinct from the yolk at its margin. In 24 hours the margin of the disc is more distinct and is showing somewhat thicker towards the centre, the boundary between the cell-mass and the yolk below being discernible in a side view. In 36 hours a distinct ridge is noticeable extending from edge to edge of the cell-mass which now covers about half of the yolk. This gradually increases in length as the mass extends over the yolk, but shows no definite thickening at any one part until after the 60th hour, although it thins out at the ends. By this time it has reached fully three-fourths of the way around the yolk. Soon after this the end, which later becomes the head, begins to thicken and become rounded off so that by the end of the third day the ridge begins to take a definite shape. During the next 12 hours much change takes place. The head becomes well defined with the eye showing, the brain and spinal cord are differentiated and several somites make their appearance, but the tail is still indistinct. The embryo reaches nearly nine-tenths of the distance around the yolk. At the end of four days the tail has become differentiated, the somites have become quite numerous, while the head is still further developed. In 4½ days the ear has made its appearance, some indication of a heart is present, and the division into somites has taken place pretty well throughout the length of the body. The embryo has increased in length so that the tail now touches the tip of the nose, a small portion of the tip being free from the yolk. During the fifth day the head and a large portion of the tail becomes free from the yolk and the body is twisted slightly so that the tip of the tail goes past the head. The heart takes more definite shape and can be seen to beat. By the end of the fifth day the embryo itself can move about and from that time on shows considerable activity in rolling about in the limited space at its disposal. From the time that bodily movement first takes place until the embryo is hatched out the change is very gradual, consisting largely of the growth and development of the organs already present. No definite time can be given for the appearance of other organs, as the rate of growth differs materially in different cases, with a corresponding difference in time for hatching out. Under normal conditions the shortest time required for hatching was 12½ days and the longest 22 days. Much greater numbers come out in from 14 to

16 days than during any other period, although in one case in a mass of 156 eggs examined, after 18 days 80 of them still contained embryos.

Before the hatching period, the median fin extends from the back of the head in a continuous line around the posterior end of the body and along the ventral surface forward to the yolk sac except where it is interrupted by the anal opening; the pectoral fins are developed also. The brain takes on much the structure of the adult brain, with the neural connection to eyes and ears; the nasal pits develop rather late. The heart becomes two-chambered but hangs rather loosely in the cavity in front of the yolk sac. The gill-slits make their appearance and the jaws are formed. The whole body remains transparent with the exception of a few small, irregular black spots along the course of the alimentary tract.

When hatched out the young herring is about 7 mm. in length and .75 mm. in depth including the fins, with a yolk-sac 1 mm. in length. The pectoral fins stand out quite prominently, but they seem to be but little used until the yolk is almost absorbed. In the newly-hatched salmon these fins are kept in rapid movement, apparently to assist in the aeration of the water, but in the herring they appear to have no such function in the early stages at any rate. The mouth is open, but the head is curved so that the mouth appears on the under side rather than at the anterior end. The gill slits are open, but as yet there are no cartilaginous supports for the arches. The alimentary tract is a tube of almost uniform size and appearance passing without convolution from the mouth to the anal opening, which is situated well towards the posterior end of the body. The liver is represented only by a couple of tubules running for some distance parallel to the alimentary tract. The kidneys are present, although they do not show much development, but the ducts can be traced readily until they join and pass out just behind the anal opening in the same papilla. There is no sign of any vertebral skeleton forming around the notochord, but this has become extensively vacuolated, so much so, that except in sagittal sections scarcely anything can be seen but the walls. The muscle segments, however, are distinctly developed, showing the regular fibrillar structure. The nasal pits are so near the undivided cerebrum that there seems to be scarcely any olfactory tracts, but the optic and the auditory nerves are well developed. The structure of the eye is practically the same as in the older forms, and in the auditory capsule the otolith, which is almost circular in cross section, is present. The optic lobes and the cerebellum are quite well developed. There is evidence of a pituitary body but none of a pineal body. The heart is not yet folded on itself, but passes back from near the symphysis of the lower jaw without showing an appreciable difference in size in its various parts.

After the embryo has hatched out there is enough yolk remaining to last it about six days. During this time the principal changes that take place have to do with the digestion and the circulation, since a preparation must be made for active feeding instead of living by absorption of food material from the yolk. The nervous system has not changed a great deal, although the pineal body is now evident. The nasal pits are relatively larger than in the younger specimens. The heart is now doubled over and shows more of a difference in the chambers. The cartilaginous skeleton has begun to develop. The basis cranii appears as a united plate forward, but farther back it separates, appearing on both sides of the pituitary body, back of which it is again united below the anterior end of the notochord. Lateral projections grow up from this base so that for a little distance the notochord is almost surrounded by cartilage. At the posterior end it supports the palatoquadrate cartilage, which is well developed, as is also Meckel's cartilage in the lower jaw. Each of the gill arches is supported by a cartilaginous rod. Except at the anterior end there is no indication of the skeletal structure appearing to encroach on the notochord; scarcely any change is noticeable in it from the time of hatching. The only other skeletal portion appearing is in the pectoral girdle, where there is a well developed cartilage on each side, but these do not come very near together in the middle line. There is as yet no indication of a pelvic girdle or pelvic fins. The mouth now opens to the full width and the lower jaw articulates freely. In the digestive tract there is now a distinct enlargement for the stomach, the walls of which are already glandular. The intestine is of uniform appearance and passes as a straight tube to the anal opening. The liver shows the greatest development of any of the organs, as now it has become a solid mass of relatively large size, showing already a division into lobes. I have not been able to make out any sign of a pancreas, although in other fish—the blue cod, *Ophiodon elongatus*, for example—it becomes quite definitely established some time before the yolk is all absorbed or even before the embryo is hatched out. The kidney and its ducts show little change.

From the time the yolk is absorbed it has not been possible yet to follow continuously the process of growth. After a couple of weeks there is a gap until the fish is about 6½ months old on Oct. 9th. By this time the average length is about 5.2 cm. and the weight 1.5 grams. The scales are already well started. On Feb. 16th they have reached a length of 6.3 cm., April 4th, 6.5 to 7.0 cm. and on May 16th (14 months), 7.6 cm.

The discussion of the appearance of the scale markings as an indication of age will not be taken up at present except to say that the areas of slow growth corresponding to the winter seasons are not so definitely marked as in the salmon scales. Since in the case of the salmon there is so much difference of opinion as to age, it would be premature to make any statements regarding the herring until all conclusions receive extensive confirmation.

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BY C. MCLEAN FRASER, PH.D.,
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I. *OPHIODON ELONGATUS* GIRARD.

Plate X, figs. 21-25

Fishes in general pay little attention to the well-being of their progeny. In oviparous forms the eggs are shed, provision is made for fertilisation and that is the end of it as far as the parent is concerned.

Among the exceptions to the general rule is *Ophiodon elongatus*, commonly known as the Blue or Green Cod. The eggs of this species are very adhesive so that after they are shed they are collected into a large mass which becomes attached to a rock, usually in a crevice or some other unevenness, a short distance below low water or occasionally in such a position that they may be exposed during a low spring tide. Over the mass the parent fish keeps guard so well that no intruder has much chance of meddling. In no case have I found the female engaged in this protective duty, but if she does not take any part, the male must have a weary vigil, as the period of incubation is about two months.

In the first instance my attention was directed rather forcibly to this characteristic of the Blue Cod. While collecting at low tide near the Biological Station, Departure Bay, I saw a mass of eggs under a rock about a foot and a half below the surface of the water. Wishing to examine some of them I managed to force off a small bunch with the blade of an oar—they stick so solidly together that this is not an easy matter—immediately after which I put down a dip net to catch them before they would sink to the bottom and was somewhat surprised with a sudden jerk that almost took the dip net out of my hand. A little later I discovered that the jerk came from a large cod that appeared from under the rock to resent the intrusion. When I thought of the sharp teeth of *Ophiodon* I was much better satisfied that the net rather than my hand received the force of the attack. The satisfaction was by no means decreased when further experiment showed how savagely he could attack starfish, nudibranchs, etc., that were lowered to test his watchfulness. Since that time the dip net has received many a jerk for a similar reason when it has been poked among the rocks in collecting. When the tide is low and the surface of the water is smooth, it is an easy matter in certain localities to see several of these fish on duty, as the opaque whiteness of the mass of eggs makes discovery an easy matter.

In the vicinity of Nanaimo spawning takes place during the latter part of January or early in February. The eggs, about 2.8 mm. in diameter, differ from the eggs of many other species in that they are so opaque that nothing can be seen of the development of the embryo with a lens or microscope, hence the early stages can be studied only by sectioning. I have not made such studies, because I considered it would be of little use to do so unless the earliest stages could be studied hour by hour, and in no case have I been certain within a day when the eggs were fertilized. Moreover, I have not had the same success in hatching out blue cod eggs in the laboratory that I have had with the eggs of other species. They seem to go bad very easily.

Although I have not got these earliest stages, I have been fortunate enough to get some embryos just hatched out. When the eyes are developed they show as dark spots in the eggs. After development had proceeded thus far I examined the eggs at intervals and thus managed to get a number hatched out shortly after they were brought into the laboratory. This was on March 25th. The newly-hatched embryo or alevin as it may now be called, is 11-12 mm. in length, with development well advanced. A certain amount of color is produced by a number of fine dark spots on the head, bands of them on each side of the dorsal fin and a less pronounced band below the lateral line. There is no break in the continuity of the median fin except at the anal opening, but there is little of it anterior to that opening. The pectoral fins are present, but they are not well developed. They do not seem to be used at all to assist respiration. There is no sign of the ventral fins.

There is not much sign of skeletal tissues. A broad plate of cartilage extends for some distance under the cerebrum, but it soon narrows and disappears before the optic chiasma is reached. At the anterior end of the notochord it again appears, forming an irregular plate of considerable size. A portion of it extends out to form part of the capsule of the ear and posteriorly it grows up around each side of the medulla almost to the mid-dorsal line, but this lasts only for a very short distance. Laterally it connects up with the articular portion of the mandible, which is slightly developed. There is a cartilaginous rod in each gill arch. The skeleton of the pectoral girdle is but slightly developed, and this only in the part some distance from the middle line, in the fin itself. The notochord is relatively rather small, and at this period is entirely vacuolated.

The nervous system is well developed. In the brain the cerebral hemispheres are almost distinct; the optic lobes are large, with the cavity separating as it passes backward; the epiphysis and the pineal body show up well; the hypophysis and the saccus vasculosus are relatively of large size, and the cranial nerves show distinctly. Judging from their appearance, the sense organs must be almost as well suited for action as they are in the adult. The nasal pits are quite deep and possess a large sensory surface, the eye has the structural characteristics and the nerve supply of the adult, while the ear is relatively of large size, and is extensively chambered with the ampullæ showing distinctly.

Although much of the yolk—there is an oil globule present—remains unabsorbed, the digestive system is apparently of high enough development to look after food taken directly from the sea. At any rate in certain other fishes there is not so high a development when the yolk is all absorbed. The mouth is of large size, with the posterior portion of the cavity in direct connection with the outside through the large gill-clefts. The digestive tube does not vary much in size throughout, but it is bent on itself to form a loop of considerable length. The anal opening is quite far forward, a short distance posterior to the yolk-sac. The lobed liver is of large size with well developed hepatic tissue. The pancreas shows up distinctly.

The excretory organs must be strongly functional, as the kidneys have got much beyond the single tubule stage and the ducts are relatively of large size.

In the circulatory system, the heart has become quite muscular, with the chambers and general shape much the same as in the adult. The aorta with its branches through the gill arches can be traced easily, and many other of the large arteries and veins have become distinct.

Taking it as a whole the young *Ophiodon*, as it emerges from the egg, is in good condition to look after itself, although, as in the majority of young fishes, it will have enemies in plenty, enough to require the use of all its powers, no matter how fully they are developed.

II. *ONCORHYNCHUS KETA* WALBAUM:

"DOG SALMON"

Plate X, figs. 26-29

One of the characteristic sights in the shallow waters of Departure Bay near the Biological Station, during the spring months, is the continuous bubbling of the water due to the presence of myriads of young dog salmon, *Oncorhynchus keta*. This year they appeared as early as March 4th, when a few straggling schools of from 8 or 10 to 20 or 30 appeared in the shallow water near the shore. These were 30-35 mm. long, and several retained part of the yolk, although already they had the characteristic parr-marks in the majority of cases. Some of them, even when much older than this, or perhaps rather when they are much older, have no sign of the bars, so that they look very much like humpbacks. It seems scarcely possible that they are anything but dog salmon, as they are found in the same school with the barred forms, although at certain times they seem to predominate.

After watching these fry for some time, the wonder that they grow so rapidly after they reach sea water gradually disappears, as it would be hard to imagine a more active mass of condensed hunger than each of these appears to be. Watch them at any time during the day and the restless movement goes on. A snap is made at a desirable morsel here and another there, with no intermission of any length. At night when other sounds are stilled, the continuous jumping and splashing makes a ripple like that of a brook bubbling over a pebbly bed, so that it can be heard distinctly many rods away from the shore. Looking down over the water one sees them pass on in their illumined way as they disturb the various phosphorescent forms, some of which become phosphorescent no more. Occasionally when a large fish comes up with a splash to devour some of them, those fortunate enough to escape the cruel jaws, make such a speedy departure from the spot that the phosphorescence becomes more noticeable, looking like a meteoric shower in miniature.

Catch them when you will, their stomachs are gorged with food, and one would think that their digestive systems would have to work overtime to get everything assimilated. They are not particular as to their diet. Apparently anything that can be swallowed goes. If one edible species is abundant that serves very well; if there is great variety that seems to do just as well. On one occasion I found them eating nothing but dipterous insects, at another nothing but barnacle larvæ, at another nothing but appendicularia. At one time they were filled with cladocera and mollusc eggs; a few days later this was changed to amphipods and mollusc eggs. The greatest variety found at any one time appeared in two salmon caught on June 12th, 1913. In these two there were cladocera, barnacle larvæ, copepods, crustacean sloughs and mollusc eggs in abundance, a dipterous insect, a crab larva and a young mussel.

I know of no reason for their being here in such numbers unless there is an especially abundant supply of food for them. This may be so, as the waters eddy into the Bay a good deal and many of the smaller forms are apt to be brought in with the currents. Although some of them linger around the mouth of the stream near by, others remain some distance away where the water is as salt as it is out in the open, hence it seems that salinity can have nothing to do with it. They are not hatched out very near by. So far as I am aware none are hatched nearer than the Nanaimo River, the mouth of which is four miles distant. That is quite a distance for the young salmon to come through the salt water before they are out of the alevin stage.

When the yolk disappears there is no indication of any scales in the skin. About the middle of May when the fry are 40-45 mm. long, the scale makes its first appearance. It is round or oval, 0.14 to 0.2 mm. in diameter, smooth and without rings. It is the nucleus of the large scale. In a week or two the first ring appears, soon followed by others, until by the end of June, when the fry disappears from this locality, there are 8 or 9 rings surrounding the central nucleus.

Occasionally a few larger fish appear with the small ones, but I have not been able to obtain any of them. They are three or four inches long, and in all probability are dog salmon that have remained in the fresh water until the second spring instead of coming down the first spring. If one is to judge from the number that appear here, the proportion of second year fish is so low as to be almost negligible.

III. DIAGNOSIS OF FISHES BY MEANS OF THE SCALES

Plate X, figs. 30-35

A system of identification of fishes by means of their scales has been advanced by Prof. T. D. A. Cockerell, but so far the system does not seem to have met with very great favor. Yet it is quite possible that the scale can be relied upon for identification purposes at least as fully as any other single characteristic if not as fully as all others combined. Since it has been discovered that the appearance of the scales may serve as a reliable indication of the age of the fish, the study of fish scales has become almost a science in itself, and there is no doubt but that it will add materially to the means of attacking the many problems connected with the life history. Two cases of personal interest may be quoted to show the value of the study of the scales in diagnosis.

For some time after taking a special interest in the life-history of the herring, I knew nothing of the development between the time when the yolk was just absorbed and the time when the young fish was 6 cm. or over in length and had taken on the general appearance of the mature herring. On June 6th, 1913, there were numerous young fish, 35-40 mm. long, around the Government wharf on Gabriola Island. By June 12th they were plentiful around the station wharf and at other points in the neighborhood, like other young fish, with apparently ravenous appetites, feeding day and night on anything that could be swallowed. On the night of June 26th they were so numerous and were making so much disturbance in the water that I went out about 10 p.m. with a plankton net to find out what formed the food supply. There was scarcely anything but rotifers in the catch, but these were there in plenty. The stomachs of the fish were filled up with these. (Earlier in the evening the dog salmon fry were feeding almost entirely on Diptera.)

These were undoubtedly Clupeids, but were so unlike the herring of 6 or 7 cm. in some respects that I could not feel sure as to their identity. Anyone who has tried to diagnose very young fish from the descriptions given in the manuals, no matter how satisfactory they may be for mature fish, will know what a difficult job it is. The fry is often so unlike the adult in many particulars. One of the common differences occurs in a characteristic on which much stress is laid as a means of identification, *i.e.*, in the number of fin rays in the various fins. In comparing the fry of a number of species with the adults in this respect the fin rays have been found to be more numerous in the fry, the reason apparently being that from 2 to 4 of the anterior rays coalesce to form a stiffer support for the forward portion of the fin. The number of fin-rays, which one might suppose would provide one of the easiest means of identification in the fry, can in no sense be depended upon. This was one of the difficulties here. Other diagnostic features, such as the absence or presence of teeth on the vomer, can scarcely be made out with certainty, as such accessories, although present in the adult, may not yet be developed in the fry. The color cannot be depended on, for the greatest variation occurs. In this case the fish in question were much lighter in color than the older herring, and had not the metallic sheen. There was nothing in all this to prove conclusively that these fish were herring and not some other species of the Clupeid family, *Clupanodon cæruleus*, for instance, a that is found in the vicinity also.

Young as the fry were, the scales were already formed and developed sufficiently to show something of the permanent structure. The scales of the adult herring and pilchard bear considerable resemblance, although they are markedly different. The pilchard scale is much larger and has characteristic scars passing in obliquely from the margin at the sides. Since the scales of the fry were very small and corresponded to only a small portion of the adult scale, the difference in size of the adult scale did not help in the diagnosis, and as the characteristic scars of the pilchard do not pass all the way to the nucleus, it was possible that although these scars were not present, it might be that the scale had not grown enough for the beginnings to be included. An examination of several scales of each species showed that even in the central area there was a constant difference. The transverse lines are closer together in the pilchard and they show a difference in the nature of the interruption towards the median line. The scales of the fry correspond to the central portion of the herring scale rather than that of the pilchard and the question of the species was definitely settled. Three camera lucida drawings will indicate the comparison. The first is of the complete fry scale, the second of a central portion of the adult herring scale of the same size as the previous, and the third of a similar portion of an adult pilchard scale.

Later a more complete series of the young herring was obtained, both of older and younger specimens, and it seems as though the change to the appearance of the adult takes place very soon after the stage that provided the problem above indicated.

The other instance shows the value in a somewhat different direction. On June 8th, 1914, a perch or surf-fish was caught near the Station and brought in. On examination, Dr. Willey found that while in general it answered very well to the description of the white surf-fish, *Phanerodon furcatus*, yet it differed very materially in some particulars. The dorsal fin provided the most noticeable of these. In the typical *Phanerodon*, according to Jordan and Evermann, the spines are all of considerable length, gradually increasing from before backward until the last spine is often higher than the soft rays, while in the specimen the spines were all low, the last one being less than half of the length of the soft ray, exactly corresponding to the dorsal fin of a closely allied species, *Tæniotoca lateralis*. Specimens of these two species were at hand to emphasize these points.

An examination of the scales was resorted to, in order to get further light on the question. The *Phanerodon* used in comparison was a much younger and smaller specimen but the *Tæniotoca* was of full size. The scales showed the close relationship between the different species, but it was no trouble to see the marked resemblance between the scale of the young *Phanerodon* and the corresponding portion of the scale of the specimen in hand and the dissimilarity between it and that of *Tæniotoca*. (See figures 30, 31 and 32). Taking this into consideration, it was impossible to conclude otherwise than that the specimen belonged to the species *Phanerodon furcatus*.

IV. *MALLOTUS VILLOSUS* MÜLLER:

"THE CAPELIN".

Plate X, figs. 36-39.

The run of the capelin is looked forward to each year by a great number of people, who consider them quite a delicacy. They visit Departure Bay about the first of October and remain a week or ten days. The individuals deposit the spawn or milt in the sand at the water's edge, many of them being left high and dry as the wave recedes. If the surf is at all high they may be thrown up for some distance on the sand, particularly when they are chased by the arch enemy of all small fish, the dogfish. The eggs, 1.0 to 1.1 mm. in diameter, hatch out in the sand in about 30 days and the fry are carried out by the waves.

From the scale point of view the capelin is of interest on account of the effect produced by the special scales that form longitudinal bands, two above the lateral line and two below it. In the males in particular these project so prominently that distinct ridges are formed and the fish appears quadrangular. The fish themselves are small, averaging about 11 cm. in length and weighing 11 grams. The scales are correspondingly small, although it cannot be laid down as a rule that small fish have small scales and large fish large scales.

The ordinary scales are circular or oval, less than 1 mm. in diameter, with an elongated nucleus reaching almost across the scale. Around this nucleus are arranged from 8 to 12 rings. The scales that form the longitudinal bands vary much, but follow more or less two pronounced types. The one of these has an oval scale as a basis, from the margin of which extends a spike-like projection, in length about twice as great as the width of the scale. The other has not the circular base. It is about half as broad as the ordinary scale, but keeps pretty well to that size throughout except that it comes to a blunt point at its distal end. It varies in length and may be much longer than the other mentioned. In both of these the rings appear in practically the same number as in the regular scales, but they are not so complete or distinct as in the others, but simply pass from one side of the scale to the other.

If the scale starts to grow in the capelin as soon as it does in other fish, and I see no reason why it should not, this would indicate that they are but one year old when they spawn and unless larger individuals are found elsewhere, that they perish after spawning. There is some indication of this in the fact that in the latter part of the run many of them are battered up and diseased, having somewhat the same appearance as the various species of Pacific salmon after they have spawned and are dying in the streams.

EXPLANATION OF PLATES

DRAWINGS BY CLARA A. FRASER

PLATE VIII.

Fig. 1—Unincubated egg of Pacific herring, *Clupea pallasii.*
Fig. 2—Egg after 1½ hours.
Fig. 3—Egg after 2 hours.
Fig. 4—Egg after 3 hours.
Fig. 5—Egg after 4 hours.
Fig. 6—Egg after 8 hours.
Fig. 7—Egg after 12 hours.
Fig. 8—Egg after 24 hours.
Fig. 9—Egg after 36 hours.
Fig. 10—Egg after 48 hours.
Fig. 11—Egg after 60 hours.
Fig. 12—Egg after 72 hours.

NOTE.—Magnification in Figs. 1-12 24 diameters.

PLATE IX.

Fig. 13—Herring egg after 84 hours' incubation.
Fig. 14—Egg after 96 hours.
Fig. 15—Egg after 108 hours.
Fig. 16—Egg after 120 hours.
Fig. 17—Newly-hatched alevin, dorsal view.
Fig. 18—Newly-hatched alevin, ventral view.
Fig. 19—Newly-hatched alevin, side view.
Fig. 20—Fry with yolk all absorbed.

NOTE.—Figs. 13-19 magnified 24 diameters, Fig. 20 magnified 12 diameters.

PLATE X.

Fig. 21—*Ophiodon elongatus.* Newly-hatched alevin. ×15

Fig. 22—Cross section of the head in the region of the eyes. ×24. *a*, brain; *b*, eye; *c*, lens; *d*, mouth.

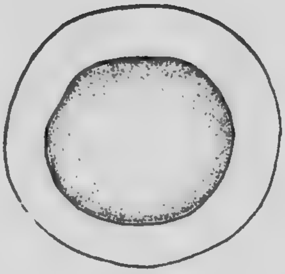
Fig. 23—Cross section of the head through the auditory organs. ×24. *a*, brain; *b*, cavity of auditory organ; *c*, dorsal aorta; *d*, basal plate; *e*, mouth cavity; *f*, gill arch; *g*, auricle; *h*, ventricle; *i*, pericardial cavity.

Fig. 24—Cross section of the body through the kidneys. ×24. *a*, spinal cord; *b*, muscle; *c*, notochord; *d*, pectoral fin; *e*, dorsal aorta; *f*, kidney; *g*, digestive tract; *h*, yolk; *i*, oil globule.

Fig. 25—Cross section of the body through the liver and pancreas. ×24. *a*, spinal cord; *b*, muscle; *c*, notocord; *d*, pancreas; *e*, digestive tract; *f*, liver; *g*, yolk; *h*, oil globule.

PLATE X—*Continued.*

Figs. 26, 27, 28, 29—Stages in the early development of the dog salmon scale. ×24.
Fig. 30—Scale of young *Phanerodon*, showing shape, distinguishing marks and centre. ×12.
Fig. 31—Central portion of scale of doubtful specimen. ×12.
Fig. 32—Central portion of *Tæniotoca* scale. ×12.
Fig. 33—Complete scale of young herring. ×24.
Fig. 34—Central portion of adult herring scale. ×24.
Fig. 35—Central portion of adult pilchard scale. ×24.
Figs. 36, 37—Ordinary scales of capelin. ×24.
Figs. 38, 39—Special capelin scales. ×24.



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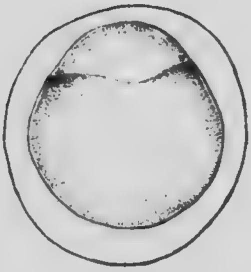

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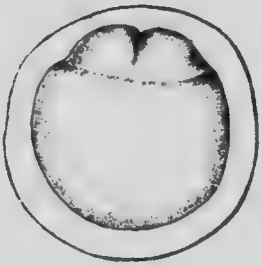

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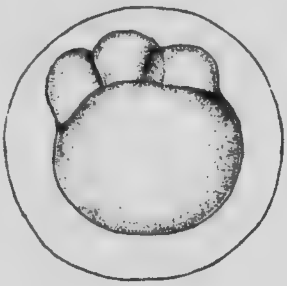

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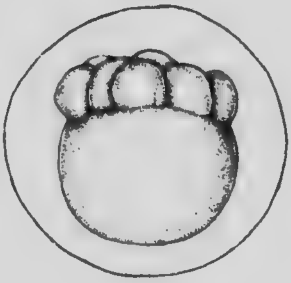

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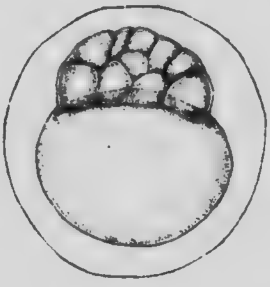

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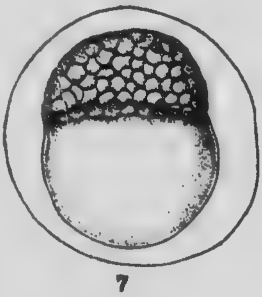

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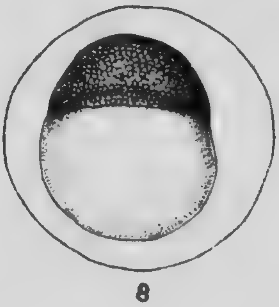

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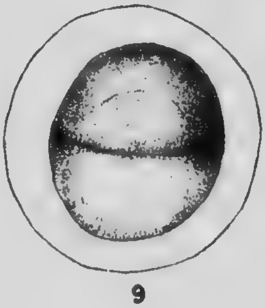

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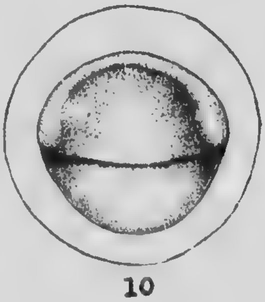

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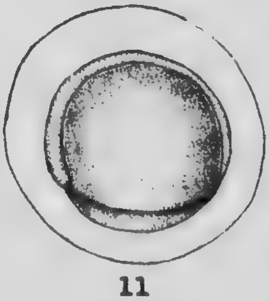

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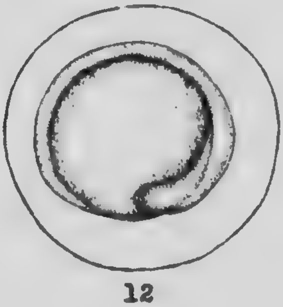

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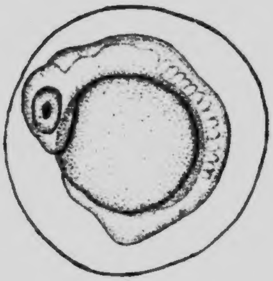

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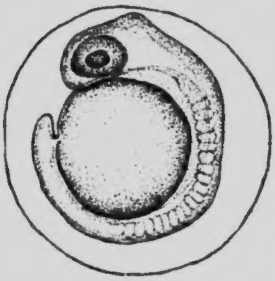

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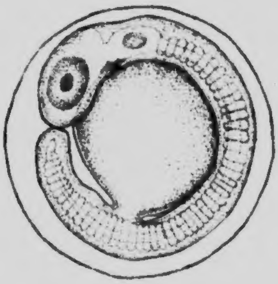

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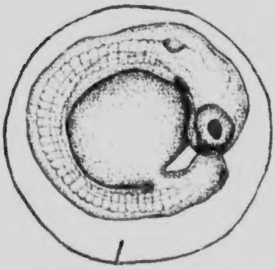

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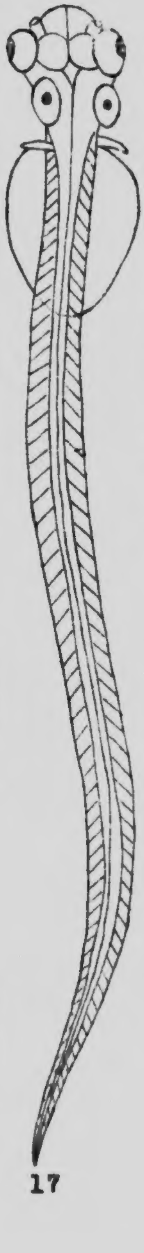

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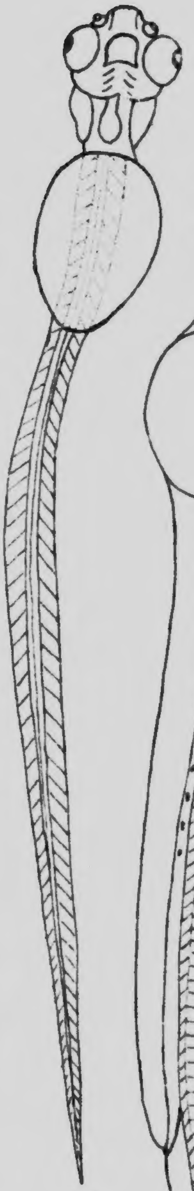

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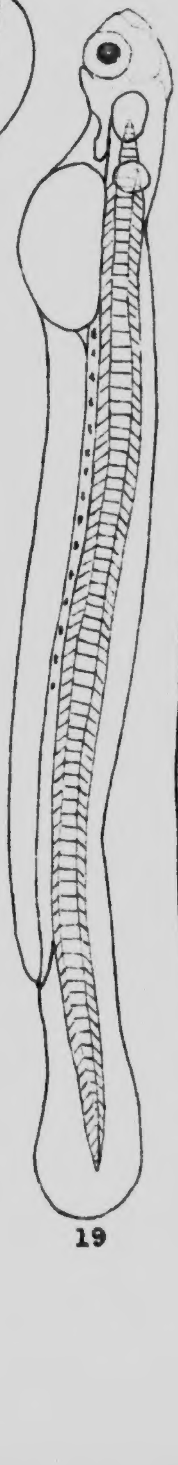

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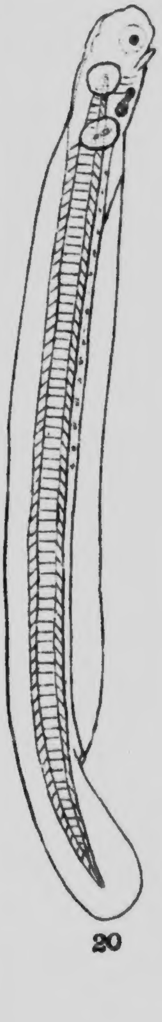

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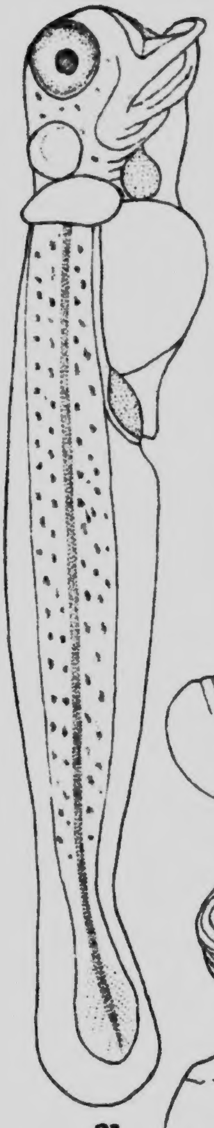

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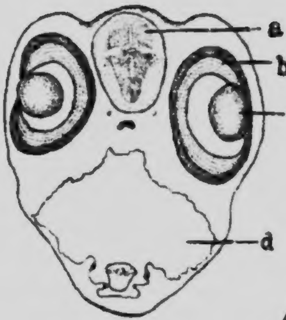

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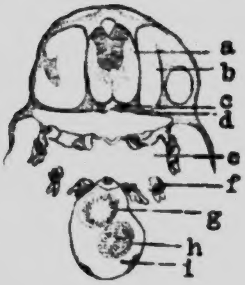

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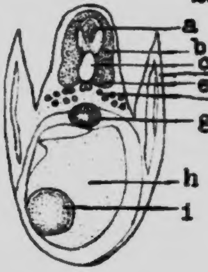

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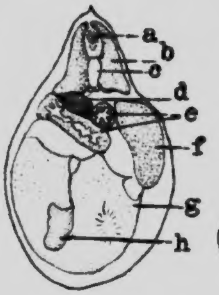

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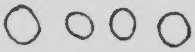

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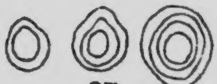

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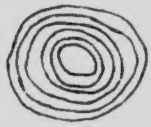

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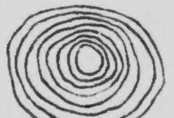

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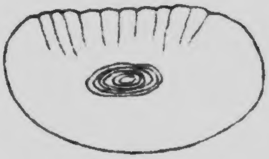

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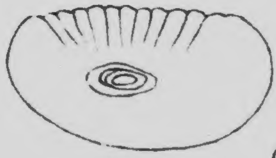

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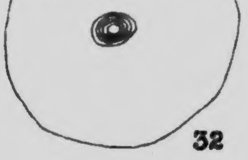

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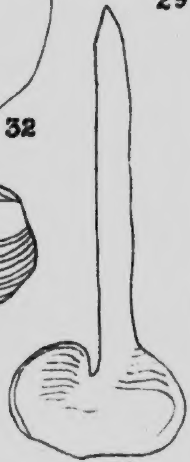

38

39

COCKAYNE, BOSTON.